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THE WHITE ROT DISEASE OF ONION BULBS.

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THE disease here described causes considerable damage to the onion crop, especially in market gardens and allotments. Until recently, however, it has not attracted serious attention, and, except in one isolated instance, it has never been the subject of scientific investigation. During the past two years the disease has been studied at the Ministry's Pathological Laboratory at Kew, and experimental work has been carried out in gardens and market gardens in that neighbourhood in which it had been found to occur. The fungus causing the disease has been isolated, grown artificially in pure culture, and the nature of its life-cycle determined. As a result of these studies the White Rot of onions has been clearly differentiated from certain diseases with which it has hitherto been confused by almost all writers. Furthermore, the fungus itself has been found to be quite distinct from two fungi (namely, *Sclerotinia bulborum* and *Botrytis cinerea*) both of which have, at one time or another, been regarded as the cause of the trouble in question, and to be identical with another parasite detected and described many years ago, but in more recent times almost entirely overlooked.

Now that the life-history of the causative organism is properly known it is possible to suggest methods for controlling the spread of the White Rot disease, although there is still room for further investigation in this direction, especially with regard to soil fungicides and trials as to the susceptibility and resistance of different varieties of onions.

The only previous account which deals in any way clearly with the White Rot disease is that* by the Italian botanist Voglino, who records its occurrence on garlic in various parts of Italy, and gives a description of the microscopic characters

* Le Stazioni sperimentati agrarie italiane, 1902. Vol. XXXVI. fasc. II., pp. 89–106.

of the fungus. This being the case a fairly full general account of the disease and the fungus causing it is given below, though technical details and other matter of purely scientific interest are omitted from the present paper.

Historical.—The destruction of onion bulbs by a fungus producing a white mould was observed by Berkeley as long ago as 1841. He described the fungus and gave it the name of *Sclerotium cepivorum*.* He states that the fungus is "very common on onions at the point from which the roots spring, and often very destructive." His description is meagre, it is true, but sufficient, nevertheless, to distinguish it from allied fungi. Berkeley's specimens, moreover, are preserved in the Herbarium at Kew; and examination of these shows that they are precisely identical with the White Rot fungus so prevalent to-day.

Since that date other forms of rotting in onion bulbs have been described, and great confusion has arisen as to the various diseases and also as to the fungi causing them. Much has been written, both in Britain and on the Continent, but with the exception of Voglino and a few quite recent writers, Berkeley's *S. cepivorum* has been more or less confused with the onion disease caused by Botrytis. No doubt the presence of the two fungi on one and the same bulb (as sometimes occurs late in the season) may partly account for this.

As a specific disease, quite distinct from Botrytis, White Rot was first correctly distinguished in this country in the Annual Report of the Plant Disease Survey of the Ministry of Agriculture for 1917 (p. 20). The popular name there employed was "Dry Rot," from the dry nature of the decay which the fungus produces. Since the term dry rot is usually associated with forms of decay occurring in storage, and as the present disease attacks the growing crops and seldom, if ever, causes trouble in storage, this term appears to be somewhat inappropriate. For this reason, therefore, another popular name, viz., "White Rot" (derived from the abundance of white mould at the base of diseased bulbs in the early stages) has been adopted, and the same name is employed in the Ministry's Plant Disease Survey Report for 1918. In Bedfordshire, where this disease is widespread, it is termed "Mouldy Nose," and in the north it is often, though erroneously, termed Mildew (see later, p. 6).

Description of the Disease.—Onions become attacked with White Rot when the soil in which they are sown or planted is contaminated with the fungus. They usually first show

* Ann. and Mag. Nat. Hist., VI., January, 1841, p. 359.

(a) (b) (c)

FIG. 1.—Autumn-sown Onions affected with White Rot, as seen in July. The destruction of the roots and the white mycelium on the bulbs is seen in specimens (b) and (c). Specimen (a) shows the formation of the small, black sclerotia at the base of the bulb.

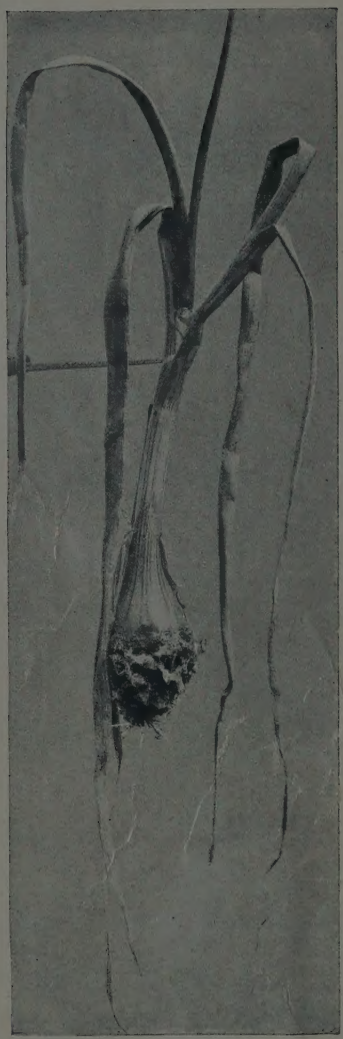

FIG. 2.

FIG. 3.

FIG. 2.—Spring-sown Onion Plant attacked by White Rot, showing the white mycelium around the base of the bulb.

FIG. 3.—A pure culture of the White Rot fungus grown on potato agar in a test tube. The culture is about a fortnight old, and shows the production of numerous black sclerotia amongst the white mycelium.

symptoms of attack at the end of May or early in June. As might be expected in the case of a disease contracted from the soil, the attack commences with individual plants located indiscriminately over the beds, but if the soil is heavily contaminated practically all the plants will be affected. Autumn-sown plants appear to be the earliest to suffer, but spring-sown onions suffer equally and, being smaller, are more quickly killed and are sometimes destroyed in large numbers.

The earliest visible symptom is one of wilting and yellowing of the foliage. The oldest leaves turn yellow and fall over, and later the other leaves also collapse. If the diseased plants are gently pulled they will be found to come up very readily, and closer examination will show that the roots have been invaded by fungus mycelium or spawn, and have been almost entirely destroyed (Figs. 1 and 2). It is probable that in all cases the roots are attacked before the bulb. Warm, damp weather appears to be specially favourable to the growth of the parasite, and when these conditions exist the fungus develops rapidly round the base of the bulb and soon covers it with a mass of fluffy white fungus-spawn or mycelium (Fig. 1 (*c*)). This white mycelium is very characteristic of the White Rot disease, and distinguishes it at once from all other diseases of the onion. When the disease is still further advanced it will be found that the fluffy mycelium has largely disappeared or has been replaced by a more closely fitting weft which penetrates also into the tissues of the bulb (Fig. 1 (*a*)). At this stage the surface of the bulb shows the presence of numerous, black, spherical bodies about the size of small poppy seed (0.5 mm. diam.) and termed sclerotia. The sclerotia are the resting bodies of the fungus (corresponding in a rough way with seeds), and it is by means of these that the parasite persists in the soil from year to year. The fungal threads continue to penetrate the tissues of the bulb, devouring the cell-contents, and forming numerous sclerotia, until finally the bulb becomes shrunken and dried up. The sclerotia are produced in large numbers on the diseased plants, and it is obvious that if the bulbs are left in the ground the soil becomes thoroughly contaminated with the fungus.

White Rot is most in evidence from the beginning of June to early August. By August it has mostly killed or destroyed the affected plants, and comparatively few new infections appear to take place after that date.

Method of Reproduction and Over-wintering.—In order to combat the disease intelligently it is essential to know the life-

history of the parasite and its methods of propagation and perpetuation.

Notwithstanding the most careful search during the last two years the only method of reproduction which has been observed is the germination of the above-described sclerotia. It has been found, by means of artificial cultures in test-tubes, that under suitable conditions of warmth and moisture these bodies put forth ordinary vegetative filaments which develop into a new growth of mycelium. The same method of germination, without doubt, takes place in the soil where the mycelium produced would invade the roots of any onion plants which were present. It would appear, therefore, that under natural conditions the sclerotia formed on the diseased bulbs in the summer remain dormant in the soil during winter, germinate in the late spring, and thus bring about the infection of the new crop.

Shortly after germination the mycelium of the fungus produces minute conidia or so-called microspores.* They are developed very freely in test-tube cultures, and were observed also on diseased onions grown under field conditions. All efforts to induce these conidia to germinate, however, failed. Similar conidia are found in certain related fungi, and these also have not been observed to germinate. Should they be capable of germination under the influence of such conditions as exist in the soil they would be of importance in that the fungus would be provided with another and partially aerial method of propagation.

In certain allied fungi (*e.g.*, *Sclerotinia sclerotiorum* on potatoes, etc., *S. trifoliorum* on clover, and *S. bulborum* on hyacinths and other ornamental bulbs), stalked, cup-shaped bodies known as ascophores, producing spores which are actively discharged into the surrounding air, are developed from the sclerotia. These bodies have not been observed, or induced to develop, in the case of the onion fungus. In order to encourage their development the usual method of subjecting the sclerotia to artificial freezing, in this way simulating winter conditions, was repeatedly tried but without effect. It would appear, therefore, that the disease is not spread by air-borne spores, but solely through the agency of sclerotia.†

* Voglino also described these bodies, but in spite of the most critical search no trace of the sphacelial stage described and figured by him as occurring on the sclerotia themselves was observed. Dr. G. H. Pethybridge informs us that this stage could not be detected in the material he examined in Ireland.

† It is for this reason that the authors prefer to retain Berkeley's generic name *Sclerotium* rather than to transfer the species to the ascomycetous genus *Sclerotinia*.

Another point of great practical importance is the length of time the sclerotia retain their vitality. It is impossible to make an exact statement as to this, since infected soil has not been long enough under examination. From accounts collected from market gardeners and others it would appear that the fungus persists in the soil for a considerable period, at least three or four years, and, judging by analogy with allied species, the sclerotia may survive considerably longer.

Method of Spread.—The introduction of the disease into new localities obviously takes place through such means as the distribution of soil containing sclerotia, the planting of diseased plants and sets, or through the careless disposal of contaminated refuse or manure. Local spread is probably chiefly accounted for through the use of contaminated manure and rubbish, or the scattering of affected soil. For the spreading over larger areas the distribution of diseased seedlings is no doubt mainly responsible. Seedling onions for planting are brought to market in quantities in April and May. These are often reared on infected land, and on more than one occasion the white mycelium of the White Rot has been noted on retail supplies. The diseased plants are distributed to gardens and allotments; and, though seedling plants probably produce but relatively few sclerotia, a sufficient number are developed to contaminate the soil, so that with subsequent crops of onions the tendency is for the disease to increase year by year. This is especially the case when onions are repeatedly grown in the same land, and very much less so when a long interval is allowed. The disease may also be spread by the use of slightly diseased "sets," when the attack is so slight as not materially to injure the bulb or to attract attention.

Susceptibility of Varieties and other Crops.—As far as the present observations go, most of the common varieties of onions appear to be subject to White Rot. Shallots, as a rule, are markedly resistant, and have been observed growing side by side with diseased onions, but remaining perfectly free from attack. On one occasion, however, shallots grown at Kew were affected and a number of bulbs were completely killed, and one other case of this crop being diseased has been observed. Leeks also do not appear to suffer as a rule, but two instances of slight attacks on leeks have been noted.

Distinctions between White Rot and other Diseases.—The effect of White Rot as seen in the foliage somewhat resembles an attack by the maggot of the Onion Fly. That disease, however,

is distinguished by the presence of the maggots in the bulbs, and the absence of the white fungus mycelium and the black sclerotia. The decay, moreover, is usually of the nature of a wet rather than a dry rot (see Leaflet No. 31.)

Of fungus diseases the most generally distributed is Mildew. This occurs as a whitish-lilac or grey mildew on the leaves, the bulb remaining free from attack (see Leaflet No. 178). Onion Smut, a recently introduced and serious disease, is distinguished by the presence of streaks of black spore-masses in the leaves and outer scales.*

The disease with which White Rot is most likely to be confused, except by expert mycologists, is that caused by the fungus named by the American botanist, M. T. Munn, *Botrytis allii*. In its typical form, however, the Botrytis disease is easy to distinguish by the fact that (1) it is the leaves and the top of the bulb rather than the roots and base of bulbs that suffer; (2) the mould which is present is grey and not white, and (3) the disease usually commences later in the year, namely, in late summer and autumn. *Botrytis* is particularly prevalent in wet seasons, and on poorly ripened bulbs. It is, indeed, often responsible for very serious losses in storage. *Botrytis* agrees with the White Rot fungus in producing sclerotia, but these are usually larger and flatter than in White Rot. Occasionally the two diseases are found in the same bulb. A full account of the Botrytis disease as it occurs in America has recently been published by M. T. Munn (New York Agric. Expt. Station (Geneva), Bull. 437, 1917).

Distribution of the Disease.—In England White Rot is very widespread, and is found especially in gardens, market gardens and allotments. In the Report of the Ministry of Agriculture's Plant Disease Survey for 1918 it is listed from 15 counties; it doubtless occurs in all parts of England. Mr. G. P. Berry, of the Ministry of Agriculture, has observed the disease near Edinburgh, and Dr. G. H. Pethybridge, of the Irish Department of Agriculture, states in a letter that it is plentiful around Dublin, but no published record exists of its occurrence in either of these countries. In some of the market gardens near London it is prevalent over extensive areas and causes much trouble, especially amongst spring onions. Near Manchester also it is said to cause very serious losses. From Voglino's account the disease is evidently serious in Italy, but owing to the confusion existing between White Rot and the Botrytis

* See this *Journal*, May, 1919, pp. 168–174.

disease little is known as to its exact distribution on the Continent. No record appears to exist of its occurrence in America.

Methods of Control.—The only means at present known of exterminating White Rot, once it becomes established in any part of a garden or field, is by starving out the fungus from the soil. This can only be effected by keeping the ground free from onions and allied crops for a number of years. The exact length of time that is necessary cannot be stated, but judging by analogy eight or even ten years may not be too long. During this period the soil should be "worked" as much as possible, although the utmost care should be taken that contaminated soil is not conveyed to clean land. It would be advisable to make any new onion beds at a considerable distance from the infested land.

When once the bulbs become attacked practically nothing can be done to save them; the disease will gradually work through and destroy the whole bulb. As a general rule and when practicable the diseased plants should be removed as early as possible before the formation of sclerotia takes place. The plants should be carefully dug up, removed from the ground and burned. If this is persisted in during the entire season further infestation of the soil by sclerotia will be prevented.

In the case of small beds in private gardens and allotments when large bulbs are affected and the attack appears to be general it may even pay to lift the entire crop at once before the whole bed becomes infected. The healthy bulbs, being immature, should not be stored but put aside for immediate consumption; the diseased bulbs (or at any rate the diseased portions of them) should be burned at once.

Up to the present no success has been obtained with the use of soil fungicides, the hard coat of the sclerotia being probably as resistant to chemicals as the spores of the Potato Wart Disease.

No varieties of onions can be recommended at present as immune. Shallots are usually resistant, and leeks are not commonly affected. These crops might, therefore, in pressing cases be grown on infested land, but it would be preferable not to do so.

White Rot is not a disease which is liable to be introduced with the seed.

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